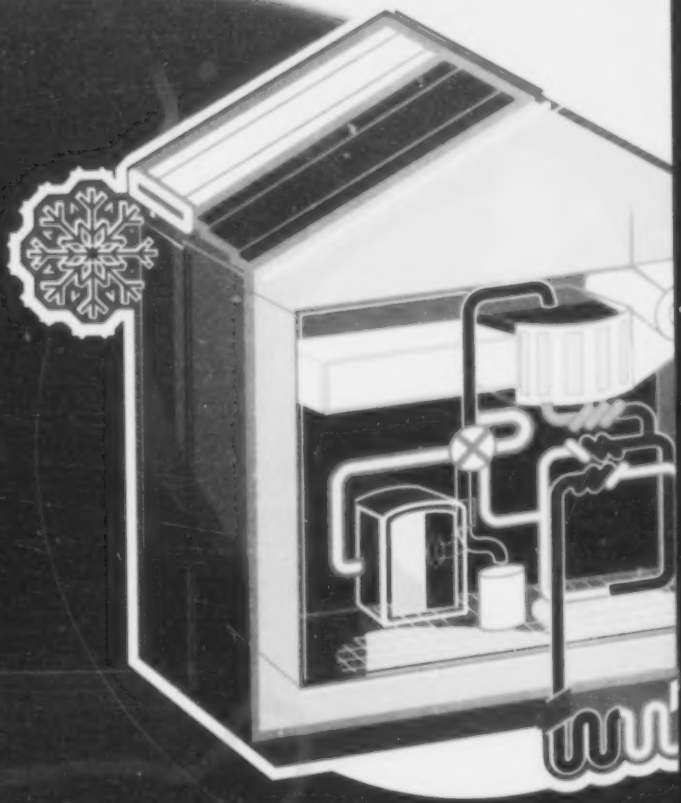
Heating and Cooling With a Heat Pump



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Heating and Cooling With a Heat Pump

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Introduction

If you are exploring the heating and cooling options for a new house or looking for ways to reduce your energy bills, you may be considering a heat pump. A heat pump can provide year-round climate control for your home by supplying heat to it in the winter and cooling it in the summer. Some types can also heat water.

In general, using a heat pump alone to meet all your heating needs may not be economical. However, used in conjunction with a supplementary form of heating, such as an oil, gas or electric furnace, a heat pump can provide reliable and economic heating in winter and cooling in summer. If you already have an oil or electric heating system, installing a heat pump may be an effective way to reduce your energy costs.

Nevertheless, it is important to consider all the benefits and costs before purchasing a heat pump. While heat pumps may have lower fuel costs than conventional heating and cooling systems, they are more expensive to buy. It is important to carefully weigh your anticipated fuel savings against the initial cost. It is also important to realize that heat pumps will be most economical when used year-round. Investing in a heat pump will make more sense if you are interested in both summer cooling and winter heating.

In addition to looking at cost, you should consider other factors. How much space will the equipment require? Will your supply of energy be interrupted on occasion? If so, how often? Will you need changes or improvements to your ducting system? How much servicing will the system need, and what will it cost?

Becoming fully informed about all aspects of home heating and cooling before making your final decision is the key to making the right choice. This booklet describes the most

common types of heat pumps, and discusses the factors involved in choosing, installing, operating, and maintaining a heat pump. A brief section on the cost of operating different types of heat pumps and conventional electric heating systems is also included.

Energy Management in the Home

Heat pumps are very efficient heating and cooling systems and can significantly reduce your energy costs. However, there is little point in investing in an efficient heating system if your home is losing heat through poorly insulated walls, ceilings, windows and doors, and by air leakage through cracks and holes.

In many cases, it makes good sense to reduce air leakage and upgrade thermal insulation levels before buying or upgrading your heating system. A number of publications explaining how to do this are available from Natural Resources Canada (see page 53).

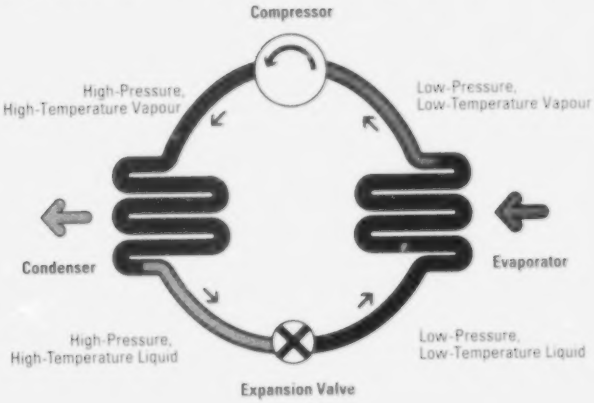
Summer Cooling May Add to Energy Bills

Heat pumps supply heat to the house in the winter and cool the house in the summer. They require electricity to operate. If you add a heat pump to your heating system or convert from another fuel to a heat pump, and your old system was not equipped with central air conditioning, you may find that your electricity bills will be higher than before.

What Is a Heat Pump and How Does It Work?

A heat pump is an electrical device that extracts heat from one place and transfers it to another. The heat pump is not a new technology; it has been used in Canada and around the world for decades. Refrigerators and air conditioners are both common examples of this technology.

Figure 1: Basic Heat Pump Cycle



Heat pumps transfer heat by circulating a substance called a refrigerant through a cycle of evaporation and condensation (see Figure 1). A compressor pumps the refrigerant between two heat exchanger coils. In one coil, the refrigerant is evaporated at low pressure and absorbs heat from its surroundings. The refrigerant is then compressed en route to the other coil, where it condenses at high pressure. At this point, it releases the heat it absorbed earlier in the cycle.

Refrigerators and air conditioners are both examples of heat pumps operating only in the cooling mode. A refrigerator is essentially an insulated box with a heat pump system connected to it. The evaporator coil is located inside the box, usually in the freezer compartment. Heat is absorbed from this location and transferred outside, usually behind or underneath the unit where the condenser coil is located. Similarly, an air conditioner transfers heat from inside a house to the outdoors.

The heat pump cycle is fully reversible, and heat pumps can provide year-round climate control for your home – heating in winter and cooling and dehumidifying in summer. Since the ground and air outside always contain some heat, a heat pump can supply heat to a house even on cold

winter days. In fact, air at –18°C contains about 85 percent of the heat it contained at 21°C.

An air-source heat pump absorbs heat from the outdoor air in winter and rejects heat into outdoor air in summer. It is the most common type of heat pump found in Canadian homes at this time. However, ground-source (also called earth-energy, geothermal, geoexchange) heat pumps, which draw heat from the ground or ground water, are becoming more widely used, particularly in British Columbia, the Prairies and Central Canada.

Coming to Terms With Heat Pumps

Here are some common terms you'll come across while investigating heat pumps.

Heat Pump Components

The **refrigerant** is the liquid/gaseous substance that circulates through the heat pump, alternately absorbing, transporting and releasing heat.

The **reversing valve** controls the direction of flow of the refrigerant in the heat pump and changes the heat pump from heating to cooling mode or vice versa.

A **coil** is a loop, or loops, of tubing where heat transfer takes place. The tubing may have fins to increase the surface area available for heat exchange.

The **evaporator** is a coil in which the refrigerant absorbs heat from its surroundings and boils to become a low-temperature vapour. As the refrigerant passes from the reversing valve to the compressor, the accumulator collects any excess liquid that didn't vaporize into a gas. Not all heat pumps, however, have an accumulator.

The **compressor** squeezes the molecules of the refrigerant gas together, increasing the temperature of the refrigerant.

The **condenser** is a coil in which the refrigerant gives off heat to its surroundings and becomes a liquid.

The **expansion** device lowers the pressure created by the compressor. This causes the temperature to drop, and the refrigerant becomes a low-temperature vapour/liquid mixture.

The **plenum** is an air compartment that forms part of the system for distributing heated or cooled air through the house. It is generally a large compartment immediately above or around the heat exchanger.

Other Terms

A **Btu/h**, or British thermal unit per hour, is a unit used to measure the heat output of a heating system. One Btu is the amount of heat energy given off by a typical birthday candle. If this heat energy were released over the course of one hour, it would be the equivalent of one Btu/h.

Heating degree-days are a measure of the severity of the weather. One degree-day is counted for every degree that the average daily temperature is below the base temperature of 18°C. For example, if the average temperature on a particular day was 12°C, six degree-days would be credited to that day. The annual total is calculated by simply adding the daily totals.

A **kW**, or **kilowatt**, is equal to 1000 watts. This is the amount of power required by ten 100-watt light bulbs.

A **ton** is a measure of heat pump capacity. It is equivalent to 3.5 kW or 12 000 Btu/h.

The **coefficient of performance (COP)** is a measure of a heat pump's efficiency. It is determined by dividing the energy output of the heat pump by the electrical energy

needed to run the heat pump, at a specific temperature. The higher the COP, the more efficient the heat pump. This number is comparable to the steady-state efficiency of oil- and gas-fired furnaces.

The **heating seasonal performance factor (HSPF)** is a measure of the total heat output in Btu of a heat pump over the entire heating season divided by the total energy in watt hours it uses during that time. This number is similar to the seasonal efficiency of a fuel-fired heating system and includes energy for supplementary heating. Weather data characteristic of long-term climatic conditions are used to represent the heating season in calculating the HSPF.

The **energy efficiency ratio (EER)** measures the steady-state cooling efficiency of a heat pump. It is determined by dividing the cooling capacity of the heat pump in Btu/h by the electrical energy input in watts at a specific temperature. The higher the EER, the more efficient the unit.

The **seasonal energy efficiency ratio (SEER)** measures the cooling efficiency of the heat pump over the entire cooling season. It is determined by dividing the total cooling provided over the cooling season in Btu by the total energy used by the heat pump during that time in watt hours. The SEER is based on a climate with an average summer temperature of 28°C.

The thermal **balance point** is the temperature at which the amount of heating provided by the heat pump equals the amount of heat lost from the house. At this point, the heat pump capacity matches the full heating needs of the house. Below this temperature, supplementary heat is required from another source.

The **economic balance point** is the temperature at which the cost of heat energy supplied by the heat pump equals the cost of heat supplied by a supplementary heating system. Below this point, it is not economical to run the heat pump.

Certification and Standards

The Canadian Standards Association (CSA) currently verifies all heat pumps for electrical safety. A performance standard specifies tests and test conditions at which heat pump heating and cooling capacities and efficiency are determined. The performance testing standards for air-source heat pumps are CSA C273.3 and C656. CSA has also published an installation standard for add-on air-source heat pumps (CSA C273.5-1980).

The industry has worked with CSA to publish standards to test the efficiency of ground-source heat pumps, and to ensure that they are designed and installed properly. These standards are CSA C13256-1-01 and C448 Series-02, respectively. Minimum efficiency standards are in place for air-source and ground-source heat pumps in some provinces and under Canada's *Energy Efficiency Regulations*.

Efficiency Terminology

The efficiency ratings for different types of heat pumps use different terminology. For example, air-source heat pumps have seasonal heating and cooling ratings. The heating rating is the HSPF; the cooling rating is the SEER. Both are defined above. However, in the manufacturers' catalogues you may still see COP or EER ratings. These are steady-state ratings obtained at one set of temperature conditions and are not the same as the HSPF or SEER ratings.

Earth-energy systems use only COP and EER ratings. Again, these ratings only hold for one temperature condition and cannot be directly used to predict annual performance in an application. In the section of this booklet titled "Major Benefits of Earth-Energy Systems" (see page 37), the COP ratings were used in a calculation to estimate HSPFs in different regions across Canada. HSPFs are not normally used to express the efficiency of earth-energy systems, but are used here to enable a comparison with air-source heat pumps.

Air-Source Heat Pumps

Air-source heat pumps draw heat from the outside air during the heating season and reject heat outside during the summer cooling season.

There are two types of air-source heat pumps. The most common is the air-to-air heat pump. It extracts heat from the air and then transfers heat to either the inside or outside of your home depending on the season.

The other type is the air-to-water heat pump, which is used in homes with hydronic heat distribution systems. During the heating season, the heat pump takes heat from the outside air and then transfers it to the water in the hydronic distribution system. If cooling is provided during the summer, the process is reversed: the heat pump extracts heat from the water in the home's distribution system and "pumps" it outside to cool the house. These systems are rare, and many don't provide cooling; therefore, most of the following discussion focuses on air-to-air systems.

More recently, ductless mini-split heat pumps have been introduced to the Canadian market. They are ideal for retrofit in homes with hydronic or electric resistance baseboard heating. They are wall-mounted, free-air delivery units that can be installed in individual rooms of a house. Up to eight separate indoor wall-mounted units can be served by one outdoor section.

Air-source heat pumps can be add-on, all-electric or bivalent. Add-on heat pumps are designed to be used with another source of supplementary heat, such as an oil, gas or electric furnace. All-electric air-source heat pumps come equipped with their own supplementary heating system in the form of electric-resistance heaters. Bivalent heat pumps are a special type, developed in Canada, that use a gas or propane fired burner to increase the temperature of the air entering the outdoor coil. This allows these units to operate at lower outdoor temperatures.

Air-source heat pumps have also been used in some home ventilation systems to recover heat from outgoing stale air and transfer it to incoming fresh air or to domestic hot water.

How Does an Air-Source Heat Pump Work?

An air-source heat pump has three cycles: the heating cycle, the cooling cycle and the defrost cycle.

The Heating Cycle

During the heating cycle, heat is taken from outdoor air and "pumped" indoors.

- First, the liquid refrigerant passes through the expansion device, changing to a low-pressure liquid/vapour mixture. It then goes to the outdoor coil, which acts as the evaporator coil. The liquid refrigerant absorbs heat from the outdoor air and boils, becoming a low-temperature vapour.

- This vapour passes through the reversing valve to the accumulator, which collects any remaining liquid before the vapour enters the compressor. The vapour is then compressed, reducing its volume and causing it to heat up.

- Finally, the reversing valve sends the gas, which is now hot, to the indoor coil, which is the condenser. The heat from the hot gas is transferred to the indoor air, causing the refrigerant to condense into a liquid. This liquid returns to the expansion device and the cycle is repeated. The indoor coil is located in the ductwork, close to the furnace.

The ability of the heat pump to transfer heat from the outside air to the house depends on the outdoor temperature. As this temperature drops, the ability of the heat pump to absorb heat also drops.

At the outdoor ambient balance point temperature, the heat pump's heating capacity is equal to the heat loss of the house.

Below this outdoor ambient temperature, the heat pump can supply only part of the heat required to keep the living space comfortable, and supplementary heat is required.

When the heat pump is operating in the heating mode without any supplementary heat, the air leaving it will be cooler than air heated by a normal furnace. Furnaces generally deliver air to the living space at between 55°C and 60°C. Heat pumps provide air in larger quantities at about 25°C to 45°C and tend to operate for longer periods.

The Cooling Cycle

The cycle described above is reversed to cool the house during the summer. The unit takes heat out of the indoor air and rejects it outside.

- As in the heating cycle, the liquid refrigerant passes through the expansion device, changing to a low-pressure liquid/vapour mixture. It then goes to the indoor coil, which acts as the evaporator. The liquid refrigerant absorbs heat from the indoor air and boils, becoming a low-temperature vapour.

- This vapour passes through the reversing valve to the accumulator, which collects any remaining liquid, and then to the compressor. The vapour is then compressed, reducing its volume and causing it to heat up.

- Finally, the gas, which is now hot, passes through the reversing valve to the outdoor coil, which acts as the condenser. The heat from the hot gas is transferred to the outdoor air, causing the refrigerant to condense into a liquid. This liquid returns to the expansion device, and the cycle is repeated.

During the cooling cycle, the heat pump also dehumidifies the indoor air. Moisture in the air passing over the indoor coil condenses on the coil's surface and is collected in a pan at the bottom of the coil. A condensate drain connects this pan to the house drain.

The Defrost Cycle

If the outdoor temperature falls to near or below freezing when the heat pump is operating in the heating mode, moisture in the air passing over the outside coil will condense and freeze on it. The amount of frost buildup depends on the outdoor temperature and the amount of moisture in the air.

This frost buildup decreases the efficiency of the coil by reducing its ability to transfer heat to the refrigerant. At some point, the frost must be removed. To do this, the heat pump will switch into the defrost mode.

- First, the reversing valve switches the device to the cooling mode. This sends hot gas to the outdoor coil to melt the frost. At the same time the outdoor fan, which normally blows cold air over the coil, is shut off in order to reduce the amount of heat needed to melt the frost.

- While this is happening, the heat pump is cooling the air in the ductwork. The heating system would normally warm this air as it is distributed throughout the house.

One of two methods is used to determine when the unit goes into defrost mode. Demand-frost controls monitor airflow, refrigerant pressure, air or coil temperature and pressure differential across the outdoor coil to detect frost accumulation on the outdoor coil.

Time-temperature defrost is started and ended by a preset interval timer or a temperature sensor located on the outside coil. The cycle can be initiated every 30, 60 or 90 minutes, depending on the climate and the design of the system.

Unnecessary defrost cycles reduce the seasonal performance of the heat pump. As a result, the demand-frost method is generally more efficient since it starts the defrost cycle only when it is required.

Figure 2a: Components of an Air-source Heat Pump (Heating Cycle)

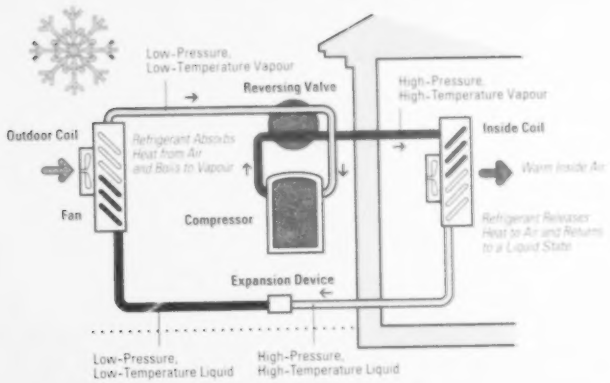
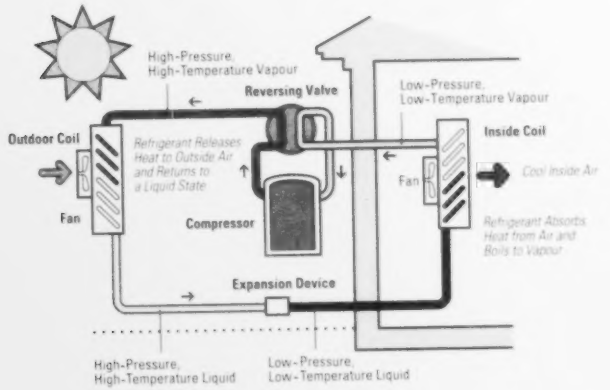


Figure 2b: Components of an Air-source Heat Pump (Cooling Cycle)

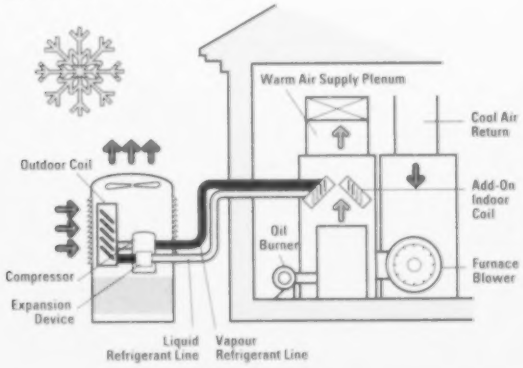


Parts of the System

The components of an air-source heat pump are shown in Figure 2a and Figure 2b. In addition to the indoor and outdoor coils, the reversing valve, the expansion device, the compressor, and the piping, the system has fans that blow air over the coils and a supplementary heat source. The compressor can be located indoors or outdoors.

If the heat pump is all-electric, supplementary heat will be supplied by a series of resistance heaters located in the main air-circulation space or plenum downstream of the heat pump indoor coil. If the heat pump is an add-on unit (see Figure 3), the supplementary heat will be supplied by a furnace. The furnace may be electric, oil, natural gas or propane. The indoor coil of the heat pump is located in the air plenum, usually just above the furnace. See the section titled "Supplementary Heating Systems," on page 46, for a description of the operation of a heat pump and furnace combination. In the case of a ductless mini-split heat pump, supplementary heat can be provided by the existing hydronic or electric resistance baseboard heaters.

Figure 3: Add-On Heat Pump



Energy Efficiency Considerations

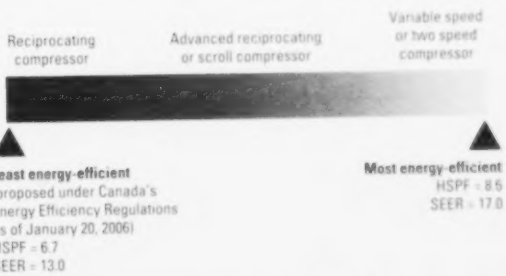
The annual cooling efficiency (SEER) and heating efficiency (HSPF) of an air-source heat pump are affected by the manufacturer's choice of features. At the time of this publication, the SEER of air-source heat pumps ranged from a minimum of 10 to a maximum of about 17. The HSPF for the same units ranged from a minimum of 5.9 to a maximum of 8.6, for a Region V climate as required in CSA C656. Region V has a climate similar to that of Ottawa.

The minimum efficiency levels above are currently regulated in a number of jurisdictions. New minimum efficiency requirements are scheduled to come into effect across Canada in 2006. The minimum SEER will likely be 13, and the minimum HSPF will be 6.7. These levels represent a significant improvement over the average sales-weighted efficiency from only a few years ago. More efficient compressors, larger heat exchanger surfaces, improved refrigerant flow and other controls are largely responsible for these gains. New developments in compressors, motors and controls will push the limits of efficiency even higher.

More advanced compressor designs by different manufacturers (advanced reciprocating, scroll, variable-speed or two-speed compressors combined with current best heat exchanger and control designs) permit SEERs as high as 17 and HSPFs of up to 8.6 for Region V.

Air-source heat pumps at the lower end of the efficiency range are characterized as having single-speed reciprocating compressors. Higher efficiency units generally incorporate scroll or advanced reciprocating compressors, with no other apparent design differences. Heat pumps with the highest SEERs and HSPFs invariably use variable- or two-speed scroll compressors.

Figure 4: Air-Source Heat Pump Efficiency (Region V)


Reciprocating compressor
Advanced reciprocating or scroll compressor
Variable speed or two speed compressor
Least energy-efficient
(proposed under Canada's Energy Efficiency Regulations as of January 20, 2006)
HSPF = 6.7
SEER = 13.0
Most energy-efficient
HSPF = 8.6
SEER = 17.0

Note: Indicated values represent the range of all available equipment.

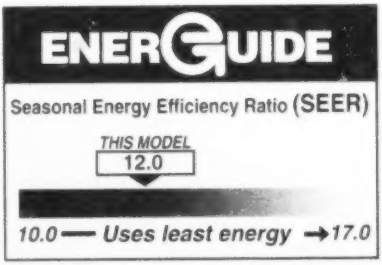
The EnerGuide Ratings for Heat Pumps

Natural Resources Canada (NRCan) and the Heating, Refrigerating and Air Conditioning Institute of Canada (HRAI) have established an industry-managed energy efficiency rating system for furnaces, central air conditioners and air-to-air heat pumps. The energy efficiency rating scale appears under the EnerGuide logo on the manufacturers' brochures (see Figure 5). As with the EnerGuide label for room air conditioners, the inverted triangle and graduated bar can be used to compare a particular model with other model designs and types.

Figure 5: EnerGuide Rating for Central Air Conditioners and Heat Pumps

The energy efficiency for air-to-air heat pump (cooling mode) is measured by SEER (seasonal energy efficiency ratio). The higher the number, the more energy-efficient the model.

Note: There is an EnerGuide rating for every model, not just for the most energy-efficient ones.



Lowest energy efficiency level permitted for sale in Canada for central air conditioners and heat pumps (cooling mode) in accordance with provincial and federal regulations.

This indicator tells you the energy efficiency of the model featured in the brochure, compared with the SEER rating of all units available for sale in Canada. In some cases, there may be a range of numbers shown in this box and two arrows pointing to the rating line. This indicates that there is more than one model or size referenced in the brochure. The range represents the lowest and the highest SEER ratings for the models featured in the brochure.

Highest SEER available in Canada for this type and category of model.

ENERGY STAR®

Today's ENERGY STAR® qualified air-to-air heat pumps use up to 20 percent less energy than standard new models. The ENERGY STAR specifications require that the EnerGuide SEER rating be 12.0 or greater for a single package unit or 13.0 or greater for a split system.

By choosing to buy an ENERGY STAR qualified heat pump that is sized correctly for your home, you can help to reduce emissions of GHGs and smog precursors, realize substantial electrical savings and increase your household's comfort.

Other Selection Considerations

Select a unit with as high an HSPF as practical. For units with comparable HSPF ratings, check their steady-state ratings at –8.3°C, the low temperature rating. The unit with the higher value will be the most efficient one in most regions of Canada.

Select a unit with demand-defrost control. This minimizes defrost cycles (system reversals are hard on the machine), which reduces supplementary and heat pump energy use.

The sound rating is a tone-corrected, A-weighted sound power level, expressed in bels. Select a heat pump with an outdoor sound rating in the vicinity of 7.6 bels or lower if possible. The sound rating is an indicator of the sound power level of the heat pump outdoor unit. The lower the value, the lower the sound power emitted by the outdoor unit. These ratings are available from the manufacturer and are published by the Air-Conditioning and Refrigeration Institute (ARI), 4301 North Fairfax Drive, Arlington, Virginia 22203, U.S.A.

Sizing Considerations

Heating and cooling loads should be determined by using a recognized sizing method such as CSA F280-M90, "Determining the Required Capacity of Residential Space Heating and Cooling Appliances."

While a heat pump can be sized to provide most of the heat required by a house, this is not generally a good idea. In Canada, heating loads are larger than cooling loads. If the heat pump is sized to match the heating load, it will be too large for the cooling requirement, and will operate only intermittently in the cooling mode. This may reduce performance and the unit's ability to provide dehumidification in the summer.

Also, as the outdoor air temperature drops, so does the efficiency of an air-source heat pump. Consequently, it doesn't make economic sense to try to meet all your heating needs with an air-source heat pump.

As a rule, an air-source heat pump should be sized to provide no more than 125 percent of the cooling load. A heat pump selected in this manner would meet about 80 to 90 percent of the annual heating load, depending on climate zone, and would have a balance point between 0°C and –5°C. This generally results in the best combination of cost and seasonal performance.

Installation Considerations

In installing any kind of heat pump, it is most important that the contractor follow manufacturers' instructions carefully. The following are general guidelines that should be taken into consideration when installing an air-source heat pump:

- In houses with a natural gas, oil or wood furnace, the heat pump coil should be installed on the warm (downstream) side of the furnace.
- If a heat pump is added to an electric furnace, the heat pump coil can usually be placed on the cold (upstream) side of the furnace for greatest efficiency.
- The outdoor unit should be protected from high winds, which may reduce efficiency by causing defrost problems. At the same time, it should be placed in the open so that outdoor air is not recirculated through the coil.

- To prevent snow from blocking airflow over the coil and to permit defrost water drainage, the unit should be placed on a stand that raises it 30 to 60 cm (12 to 24 in.) above the ground. The stand should be anchored to a concrete pad, which in turn should sit on a bed of gravel to enhance drainage. Alternatively, the unit might be mounted from the wall of the house on a suitably constructed frame.
- It is advisable to locate the heat pump outside the drip-line of the house (the area where water drips off the roof) to prevent ice and water from falling on it, which could reduce airflow or cause fan or motor damage.
- The pan under the inside coil must be connected to the house's interior floor drain, to ensure that the condensate that forms on the coil drains properly.
- The heat pump should be placed so that a serviceperson has enough room to work on the unit.
- Refrigerant lines should be as short and straight as possible. It is good practice to insulate the lines to minimize unwanted heat loss and to prevent condensation.
- Fans and compressors make noise. Locate the outdoor unit away from windows and adjacent buildings. Some units make additional noise when they vibrate. You can reduce this by selecting quiet equipment or by mounting the unit on a noise-absorbing base.
- Heat pump systems generally require larger duct sizes than other central heating systems, so existing ducting may have to be modified. For proper heat pump operation, airflow should be 50 to 60 litres per second (L/s) per kilowatt, or 400 to 450 cubic feet per minute (cfm) per ton, of cooling capacity.

The cost of installing an air-source heat pump varies depending on the type of system and the existing heating equipment. Costs will be higher if the ductwork has to be modified, or if you need to upgrade your electrical service to deal with the increased electrical load.

Operation Considerations

The indoor thermostat should be set at the desired comfort temperature (20°C is recommended) and not readjusted.

Continuous indoor fan operation can reduce the overall efficiency achieved by a heat pump system, unless a high-efficiency variable-speed fan motor is used. Operate this system with the "auto" fan setting on the thermostat.

Heat pumps have longer operation times than conventional furnaces because their heating capacity is considerably lower.

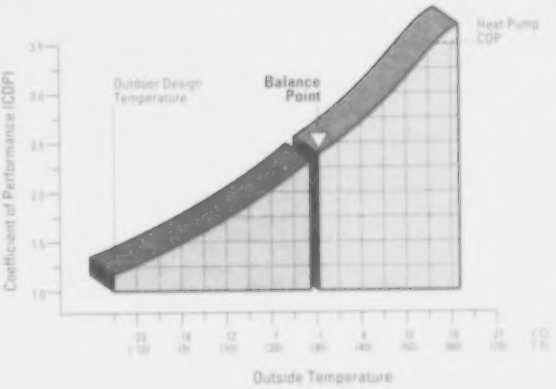
Major Benefits of Air-Source Heat Pumps

Efficiency

At 10°C, the coefficient of performance (COP) of air-source heat pumps is typically about 3.3. This means that 3.3 kilowatt hours (kWh) of heat are transferred for every kWh of electricity supplied to the heat pump. At –8.3°C, the COP is typically 2.3.

The COP decreases with temperature because it is more difficult to extract heat from cooler air. Figure 6 shows how the COP is affected by cooler air temperature. Note, however, that the heat pump compares favourably with

Figure 6: Performance Characteristics of a Typical Air-Source Heat Pump



electric resistance heating (COP of 1.0) even when the temperature falls to –15°C.

Air-source heat pumps will operate with heating seasonal performance factors (HSPFs) that vary from 6.7 to 10.0, depending on their location in Canada and their rated performance. Figure 7 shows the range of performance of

Figure 7: Heating Seasonal Performance Factors (HSPFs) for Air-Source Heat Pumps for various locations in Canada

8.7 to 10.0

Chilliwack, B.C.
Nanaimo, B.C.
Richmond, B.C.
Vancouver, B.C.
Victoria, B.C.

7.4 to 8.5

Kelowna, B.C.
Nelson, B.C.
Penticton, B.C.
Chatham, Ont.
Hamilton, Ont.
Niagara Falls, Ont.
Toronto, Ont.
Windsor, Ont.
Halifax, N.S.
Yarmouth, N.S.

6.7 to 7.4

Kamloops, B.C.
Prince Rupert, B.C.
Lethbridge, Alta.
Medicine Hat, Alta.
Maple Creek, Sask.
Barrie, Ont.
Kingston, Ont.
Kitchener, Ont.
London, Ont.
North Bay, Ont.
Ottawa, Ont.
Sault Ste. Marie, Ont.
Sudbury, Ont.
Montreal, Que.
Quebec, Que.
Sherbrooke, Que.
Moncton, N.B.
Saint John, N.B.
Amherst, N.S.
Sydney, N.S.
Charlottetown, P.E.I.
Grand Bank, N.L.
St. John's, N.L.

Note: Indicated values represent the range from "standard efficiency" to "high-efficiency" equipment.

air-source heat pumps operating in various regions in Canada. For this booklet, we have identified three regions where it would be viable to use air-source heat pumps. The first region is the West Coast, characterized as mild with high heat pump performance. The second region – southern Ontario, Nova Scotia and interior British Columbia – is colder, and requires a heat pump with higher performance. The third region includes colder regions in British Columbia, Alberta, Ontario, Quebec, New Brunswick, Nova Scotia, Prince Edward Island, and Newfoundland and Labrador. Outside these regions, air-source heat pumps are not as economically attractive.

Energy Savings

You may be able to reduce your heating costs by up to 50 percent if you convert from an electric furnace to an all-electric air-source heat pump. Your actual savings will vary, depending on factors such as local climate, the efficiency of your current heating system, the cost of fuel and electricity, and the size and HSPF of the heat pump installed.

More advanced designs of air-source heat pumps can provide domestic water heating. Such systems are called "integrated" units because heating of domestic water has been integrated with a house space-conditioning system. Water heating can be provided with high efficiency in this way. Water heating bills can be reduced by 25 to 50 percent.

Maintenance

Proper maintenance is critical to ensure that your heat pump operates efficiently and has a long service life. You can do some of the simple maintenance yourself, but you may also want to have a competent service contractor do an annual inspection of your unit. The best time to service your unit is at the end of the cooling season, prior to the start of the next heating season.

- Filter and coil maintenance has a dramatic impact on system performance and service life. Dirty filters, coils and

fans reduce airflow through the system. This reduces system performance, and can lead to compressor damage if it continues for extended periods of time.

Filters should be inspected monthly and cleaned or replaced as required by the manufacturer's instructions. The coils should be vacuumed or brushed clean at regular intervals as indicated in the manufacturer's instruction booklet. The outdoor coil may be cleaned using a garden hose. While cleaning filters and coils, look for symptoms of other potential problems such as those described on the following page.

- The fan should be cleaned but the fan motor should only be lubricated if the manufacturer instructions specify this. This should be done annually to ensure that the fan provides the airflow required for proper operation. The fan speed should be checked at the same time. Incorrect pulley settings, loose fan belts, or incorrect motor speeds in the case of direct drive fans can all contribute to poor performance.

- Ductwork should be inspected and cleaned as required to ensure that airflow is not restricted by loose insulation, abnormal buildup of dust, or any other obstacles that occasionally find their way through the grilles.

- Be sure that vents and registers are not blocked by furniture, carpets or other items that can block airflow. As noted earlier, extended periods of inadequate airflow can lead to compressor damage.

You will need to hire a competent service contractor to do more difficult maintenance such as checking the refrigerant level and making electrical or mechanical adjustments.

Service contracts are similar to those for oil and gas furnaces. But heat pumps are more sophisticated than conventional equipment and, therefore, can have higher average service costs.

Operating Costs

The energy costs of a heat pump can be lower than those of other heating systems, particularly electric or oil heating systems.

However, the relative savings will depend on whether you are currently using electricity, oil, propane or natural gas, and on the relative costs of different energy sources in your area. By running a heat pump, you will use less gas or oil, but more electricity. If you live in an area where electricity is expensive, your operating costs may be higher. Depending on these factors, the payback period for investment in an air-source heat pump rather than a central air conditioner could be anywhere from two to seven years. Later in this booklet, heating energy cost comparisons between air-source and ground-source heat pumps and electric and oil heating systems will be made.

Life Expectancy and Warranties

Air-source heat pumps have a service life of between 15 and 20 years. The compressor is the critical component of the system.

Most heat pumps are covered by a one-year warranty on parts and labour, and an additional five- to ten-year warranty on the compressor (for parts only). However, warranties vary between manufacturers, so check the fine print.

Ground-Source Heat Pumps (Earth-Energy Systems)

A ground-source heat pump uses the earth or ground water or both as the sources of heat in the winter, and as the "sink" for heat removed from the home in the summer. For this reason, ground-source heat pump systems have come to be known as earth-energy systems (EESs). Heat is

removed from the earth by using a liquid, such as ground water or an antifreeze solution; the liquid's temperature is raised by the heat pump; and the heat is transferred to indoor air. During summer months, the process is reversed: heat is taken from indoor air and transferred to the earth by the ground water or antifreeze solution. A direct-expansion (DX) earth-energy system uses refrigerant in the ground-heat exchanger, instead of an antifreeze solution.

Earth-energy systems can be used with forced-air and hydronic heating systems. They can also be designed and installed to provide heating only, heating with "passive" cooling, or heating with "active" cooling. Heating-only systems do not provide cooling. Passive-cooling systems provide cooling by pumping cool water or antifreeze through the system without using the heat pump to assist the process. Active cooling is provided as described below, in "The Cooling Cycle."

How Does an Earth-Energy System Work?

All EESs have two parts: a circuit of underground piping outside the house, and a heat pump unit inside the house. Unlike the air-source heat pump, where one heat exchanger (and frequently the compressor) is located outside, the entire ground-source heat pump unit is located inside the house.

The outdoor piping system can be either an open system or closed loop. An open system takes advantage of the heat retained in an underground body of water. The water is drawn up through a well directly to the heat exchanger, where its heat is extracted. The water is discharged either to an above-ground body of water, such as a stream or pond, or back to the same underground water body through a separate well.

Closed-loop systems collect heat from the ground by means of a continuous loop of piping buried underground. An antifreeze solution (or refrigerant in the case of a DX earth-energy system), which has been chilled by the heat

pump's refrigeration system to several degrees colder than the outside soil, circulates through the piping and absorbs heat from the surrounding soil.

The Heating Cycle

In the heating cycle, the ground water, the antifreeze mixture or the refrigerant (which has circulated through the underground piping system and picked up heat from the soil) is brought back to the heat pump unit inside the house. In ground water or antifreeze mixture systems, it then passes through the refrigerant-filled primary heat exchanger. In DX systems, the refrigerant enters the compressor directly, with no intermediate heat exchanger.

The heat is transferred to the refrigerant, which boils to become a low-temperature vapour. In an open system, the ground water is then pumped back out and discharged into a pond or down a well. In a closed-loop system, the antifreeze mixture or refrigerant is pumped back out to the underground piping system to be heated again.

The reversing valve directs the refrigerant vapour to the compressor. The vapour is then compressed, which reduces its volume and causes it to heat up.

Finally, the reversing valve directs the now-hot gas to the condenser coil, where it gives up its heat to the air that is blowing across the coil and through the duct system to heat the home. Having given up its heat, the refrigerant passes through the expansion device, where its temperature and pressure are dropped further before it returns to the first heat exchanger, or to the ground in a DX system, to begin the cycle again.

Domestic Hot Water

In some EFSs, a heat exchanger, sometimes called a "desuperheater," takes heat from the hot refrigerant after it leaves the compressor. Water from the home's water heater is pumped through a coil ahead of the condenser coil, in order that some of the heat that would have been dissipated at the condenser is used to heat water. Excess

heat is always available in the summer cooling mode, and is also available in the heating mode during mild weather when the heat pump is above the balance point and not working to full capacity. Other EESs provide domestic hot water (DHW) on demand: the whole machine switches to providing DHW when it is required.

Water heating is easier with EESs because the compressor is located indoors. Because EESs have relatively constant heating capacity, they generally have many more hours of surplus heating capacity than required for space heating.

The Cooling Cycle

The cooling cycle is basically the reverse of the heating cycle. The direction of the refrigerant flow is changed by the reversing valve. The refrigerant picks up heat from the house air and transfers it directly, in DX systems, or to the ground water or antifreeze mixture. The heat is then pumped outside, into a water body or return well (in an open system) or into the underground piping (in a closed-loop system). Once again, some of this excess heat can be used to preheat domestic hot water.

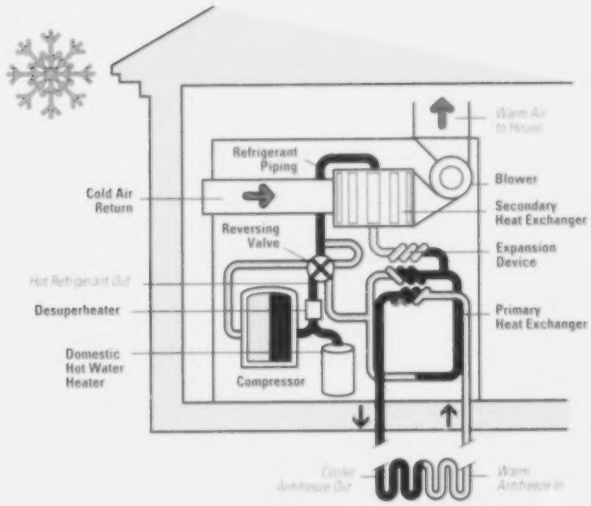
Unlike air-source heat pumps, EESs do not require a defrost cycle. Temperatures underground are much more stable than air temperatures, and the heat pump unit itself is located inside; therefore, the problems with frost do not arise.

Parts of the System

As shown in Figure 8, earth-energy systems have three main components: the heat pump unit itself, the liquid heat exchange medium (open system or closed loop), and the air delivery system (ductwork).

Ground-source heat pumps are designed in different ways. Self-contained units combine the blower, compressor, heat exchanger, and condenser coil in a single cabinet. Split systems allow the coil to be added to a forced-air furnace, and use the existing blower and furnace.

Figure 8: Components of a Typical Ground-Source Heat Pump



Energy Efficiency Considerations

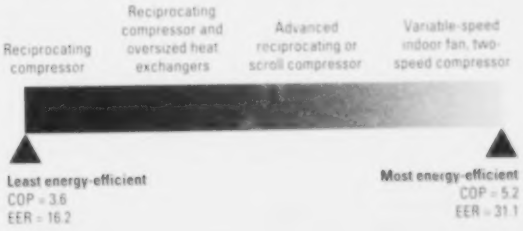
As with air-source heat pumps, earth-energy systems are available with widely varying efficiency ratings. Earth-energy systems intended for ground-water or open-system applications have heating COP ratings ranging from 3.6 to 5.2, and cooling EER ratings between 16.2 and 31.1(see Figure 9). Those intended for closed-loop applications have heating COP ratings between 3.1 and 4.9, while EER ratings range from 13.4 to 25.8 (see Figure 10).

The minimum efficiency in each range is regulated in the same jurisdictions as the air-source equipment. There has been a dramatic improvement in the efficiency of earth-energy systems. Today, the same new developments in compressors, motors and controls that are available to air-source heat pump manufacturers are resulting in higher levels of efficiency for earth-energy systems.

In the lower to middle efficiency range, earth-energy systems use single-speed rotary or reciprocating compressors, relatively standard refrigerant-to-air ratios, but oversized enhanced-surface refrigerant-to-water heat exchangers.

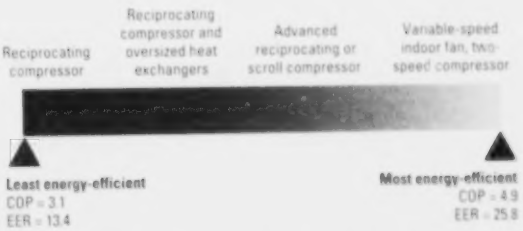
Mid-range units employ scroll compressors or advanced reciprocating compressors. Units in the high efficiency range tend to use two-speed compressors or variable-speed indoor fan motors or both, with more or less the same heat exchangers.

Figure 9: Open System Earth-Energy System Efficiency (at an entering water temperature of 10°C)



Note: Indicated values represent the range of all available equipment.

Figure 10: Closed-Loop Earth-Energy System Efficiency (at an entering antifreeze temperature of 0°C)



Note: Indicated values represent the range of all available equipment.

ENERGY STAR®

Earth-energy systems now can be qualified under Canada's ENERGY STAR® High Efficiency Initiative. In Canada, ENERGY STAR currently includes the following product specifications for earth-energy systems:

Table 1:

Key ENERGY STAR Criteria for Ground-Source Heat Pumps (2004)

Product Type	Minimum EER	Minimum COP	Water Heating (WH)
Closed-loop	14.1	3.3	Yes
• with integrated WH	14.1	3.3	N/A
Open-loop	16.2	3.6	Yes
• with integrated WH	16.2	3.6	N/A
DX	15.0	3.5	Yes
• with integrated WH	15.0	3.5	N/A

To be allowed to display the ENERGY STAR symbol, products must meet or exceed technical specifications designed to ensure that they are among the most energy efficient in the marketplace. Minimum requirements vary from one category to another, but typically an ENERGY STAR model must be from 10 to 50 percent more efficient than a conventional model.

Sizing Considerations

Unlike the outside air, the temperature of the ground remains fairly constant. As a result, the output of an EES varies little throughout the winter. Since the EES's output is relatively constant, it can be designed to meet almost all the space heating requirement – with enough capacity left to provide water heating as an "extra."

As with air-source heat pump systems, it is generally not a good idea to size an EES to provide all of the heat required by a house. For maximum cost-effectiveness, an EES should be sized to meet 60 to 70 percent of the total maximum "demand load" (the total space heating and water heating requirement). The occasional peak heating load during severe weather conditions can be met by a supplementary heating system. A system sized in this way will in fact supply about 95 percent of the total energy used for space heating and water heating.

EESs with variable speed or capacity are available in two-speed compressor configurations. This type of system can meet all cooling loads and most heating loads on low speed, with high speed required only for high heating loads.

A variety of sizes of EESs are available to suit the Canadian climate. Units range in size from 7 kW to 35 kW (24 000 to 120 000 Btu/h), and include domestic hot water (DHW) options.

Design Considerations

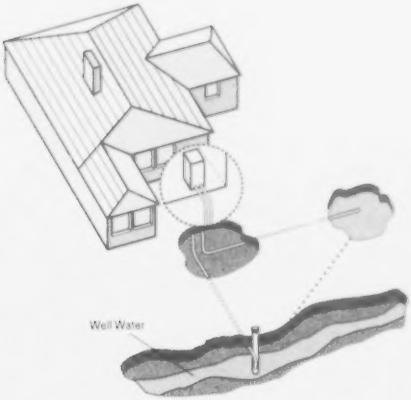
Unlike air-source heat pumps, EESs require that a well or loop system be designed to collect and dissipate heat underground.

Open Systems

As noted, an open system (see Figure 11) uses ground water from a conventional well as a heat source. The

ground water is pumped into the heat pump unit, where heat is extracted. Then, the "used" water is released in a stream, pond, ditch, drainage tile, river or lake. This process is often referred to as the "open discharge" method. (This may not be acceptable in your area. Check with local authorities.)

Figure 11: Open System Using Groundwater From a Well as a Heat Source



Another way to release the used water is through a rejection well, which is a second well that returns the water to the ground. A rejection well must have enough capacity to dispose of all the water passed through the heat pump, and should be installed by a qualified well driller. If you have an extra existing well, your heat pump contractor should have a well driller ensure that it is suitable for use as a rejection well. Regardless of the approach used, the system should be designed to prevent any environmental damage. The heat pump simply removes or adds heat to the water; no pollutants are added. The only change in the water returned to the environment is a slight increase or decrease in temperature.

The size of the heat pump unit and the manufacturer's specifications will determine the amount of water that is needed for an open system. The water requirement for a specific model of heat pump is usually expressed in litres per second (L/s) and is listed in the specifications for that unit. A heat pump of 10-kW (34 000-Btu/h) capacity will use 0.45 to 0.75 L/s while operating.

Your well and pump combination should be large enough to supply the water needed by the heat pump in addition to your domestic water requirements. You may need to enlarge your pressure tank or modify your plumbing to supply adequate water to the heat pump.

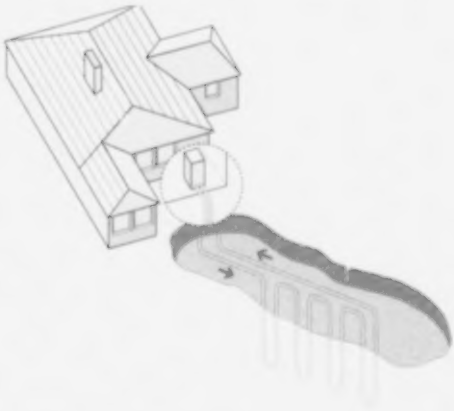
Poor water quality can cause serious problems in open systems. You should not use water from a spring, pond, river or lake as a source for your heat pump system unless it has been proven to be free of excessive particles and organic matter, and warm enough throughout the year (typically over 5°C) to avoid freeze-up of the heat exchanger. Particles and other matter can clog a heat pump system and make it inoperable in a short period of time. You should also have your water tested for acidity, hardness and iron content before installing a heat pump. Your contractor or equipment manufacturer can tell you what level of water quality is acceptable and under what circumstances special heat-exchanger materials may be required. Installation of an open system is often subject to local zoning laws or licensing requirements. Check with local authorities to determine if restrictions apply in your area.

Closed-Loop Systems

A closed-loop system draws heat from the ground itself, using a continuous loop of special buried plastic pipe. Copper tubing is used in the case of DX systems. The pipe is connected to the indoor heat pump to form a sealed underground loop through which an antifreeze solution or refrigerant is circulated. While an open system drains water from a well, a closed-loop system recirculates its heat transfer solution in pressurized pipe.

The pipe is placed in one of two types of arrangements: vertical or horizontal. A vertical closed-loop arrangement (see Figure 12) is an appropriate choice for most suburban homes, where lot space is restricted. Piping is inserted into bored holes that are 150 mm (6 in.) in diameter, to a depth of 18 to 60 m (60 to 200 ft.), depending on soil conditions and the size of the system. Usually, about 80 to 110 m (270 to 350 ft.) of piping is needed for every ton (3.5 kW or 12 000 Btu/h) of heat pump capacity. U-shaped loops of pipe are inserted in the holes. DX systems can have smaller diameter holes, which can lower drilling costs.

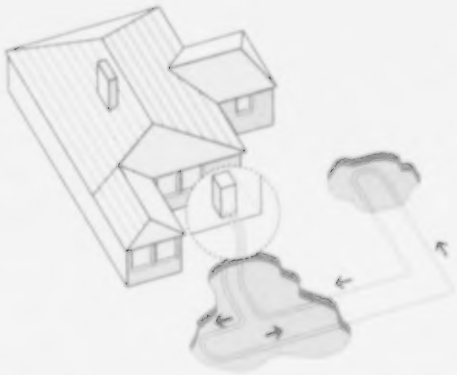
Figure 12: Closed-Loop, Single U-Bend Vertical Configuration



The horizontal arrangement (see Figure 13) is more common in rural areas, where properties are larger. The pipe is placed in trenches normally 1.0 to 1.8 m (3 to 6 ft.) deep, depending on the number of pipes in a trench. Generally, 120 to 180 m (400 to 600 ft.) of pipe are required per ton of heat pump capacity. For example, a well-insulated, 185 m^2 (2000 sq. ft.) home would probably need a three-ton system with 360 to 540 m (1200 to 1800 ft.) of pipe.

The most common horizontal heat exchanger design is two pipes placed side-by-side in the same trench. Another heat exchanger sometimes used where area is limited is a

Figure 13: Closed-Loop, Single Layer Horizontal Configuration



"spiral" – which describes its shape. Other horizontal loop designs use four or six pipes in each trench, if land area is limited.

Regardless of the arrangement you choose, all piping for antifreeze solution systems must be at least series 100 polyethylene or polybutylene with thermally fused joints (as opposed to barbed fittings, clamps or glued joints), to ensure leak-free connections for the life of the piping. Properly installed, these pipes will last anywhere from 25 to 75 years. They are unaffected by chemicals found in soil and have good heat-conducting properties. The antifreeze solution must be acceptable to local environmental officials. DX systems use refrigeration-grade copper tubing.

Neither vertical nor horizontal loops have an adverse impact on the landscape as long as the vertical boreholes and trenches are properly backfilled and tamped (packed down firmly).

Horizontal loop installations use trenches anywhere from 150 to 600 mm (6 to 24 in.) wide. This leaves bare areas that can be restored with grass seed or sod. Vertical loops require little space and result in minimal lawn damage.

It is important that horizontal and vertical loops be installed by a qualified contractor. Plastic piping must be thermally fused, and there must be good earth-to-pipe contact to ensure good heat transfer, such as that achieved by Tremie-grouting of boreholes. The latter is particularly important for vertical heat-exchanger systems. Improper installation may result in less than optimum heat pump performance.

Installation Considerations

As with air-source heat pump systems, EESs must be designed and installed by qualified contractors. Consult a local heat pump contractor to design, install and service your equipment to ensure efficient and reliable operation; also, be sure that all manufacturers' instructions are followed carefully. All installations should meet the requirements of CSA C448, an installation standard set by the Canadian Standards Association.

The total installed cost of earth-energy systems varies according to site-specific conditions, but can be up to twice the cost of a gas, electric or oil furnace with add-on air conditioning. The total installed costs of open or ground water EESs can be less; the extra cost is due to ground collectors, whether they are open or closed-loop. Ductwork must be installed in homes without an existing air distribution system. The difficulty of installing ductwork will vary, and should be assessed by a contractor.

Installation costs vary depending on the type of ground collector and the equipment specifications. To be economically attractive, the incremental costs of a typical installation should be recovered through energy cost savings within five years. Check with your electric utility to assess the benefits of investing in an earth-energy system. Sometimes a low-cost financing plan or incentive is offered for approved installations.

Major Benefits of Earth-Energy Systems

Efficiency

In Canada, where air temperatures can go below –30°C, and where winter ground temperatures are generally in the range of –2°C to 4°C, earth-energy systems have a coefficient of performance (COP) of between 2.5 and 3.8.

The HSPFs in Figures 14 and 15 were calculated using a procedure very similar to that used for air-source heat pumps, but taking into account industry-sizing practice and regional ground water temperatures across Canada. Since earth-energy heat systems have both COP and EER standard performance ratings, it was necessary to calculate heating seasonal performance to compare operating costs with those of air-source heat pumps.

A ground water EES installation in southern Canada will have a heating seasonal performance factor (HSPF) of between 10.7 and 12.8, compared with an HSPF of 3.4 for electrical-resistance heating. Similarly, a closed-loop EES in southern Canada will have an HSPF of between 9.2 and 11.0, with the higher value achieved by the most efficient closed-loop heat pump available. Figure 14 (page 38) shows the HSPFs of ground water earth energy systems operating in different climatic regions in Canada, while Figure 15 (page 39) shows the same for closed-loop EESs.

Energy Savings

Earth-energy systems will reduce your heating and cooling costs substantially. Energy-cost savings compared with electric furnaces are around 65 percent.

On average, an EES will yield savings that are about 40 percent more than would be provided by an air-source heat pump. This is due to the fact that underground temperatures are higher in winter than air temperatures. As a result, an EES can provide more heat over the course of the winter than an air-source heat pump.

Figure 14: Heating Seasonal Performance Factors (HSPFs) for Ground Water or Open System EESs in Canada (left to right)

HSPF 10.8 to 13.0

Chilliwack, B.C.
Nanaimo, B.C.
Richmond, B.C.
Vancouver, B.C.
Victoria, B.C.

HSPF 10.7 to 12.8

Kelowna, B.C.
Nelson, B.C.
Penticton, B.C.
Chatham, Ont.
Hamilton, Ont.
Niagara Falls, Ont.
Toronto, Ont.
Windsor, Ont.
Halifax, N.S.
Yarmouth, N.S.

HSPF 10.1 to 12.0

Kamloops, B.C.
Prince Rupert, B.C.
Lethbridge, Alta.
Medicine Hat, Alta.
Maple Creek, Sask.
Barrie, Ont.
Kingston, Ont.
Kitchener, Ont.
London, Ont.
North Bay, Ont.
Ottawa, Ont.
Sault Ste. Marie, Ont.
Sudbury, Ont.
Montréal, Que.
Quebec, Que.
Sherbrooke, Que.
Moncton, N.B.
Saint John, N.B.
Amherst, N.S.
Sydney, N.S.
Charlottetown, P.E.I.
Grand Bank, N.L.
St. John's, N.L.

HSPF 9.9 to 11.7

Prince George, B.C.
Banff, Alta.
Calgary, Alta.
Edmonton, Alta.
Peace River, Alta.
Prince Albert, Sask.
Regina, Sask.
Saskatoon, Sask.
Brandon, Man.
Winnipeg, Man.
Thunder Bay, Ont.
Timmins, Ont.
Chicoutimi, Que.
Rimouski, Que.
Shawinigan, Que.
Edmundston, N.B.

Note: Indicated values represent the range from "standard-efficiency" to "high-efficiency" equipment.

Figure 15: Heating Seasonal Performance Factors (HSPFs) for Closed-Loop EESs in Canada (left to right)

HSPF 9.3 to 11.1

Chilliwack, B.C.
Nanaimo, B.C.
Richmond, B.C.
Vancouver, B.C.
Victoria, B.C.

HSPF 9.2 to 11.0

Kelowna, B.C.
Nelson, B.C.
Penticton, B.C.
Chatham, Ont.
Hamilton, Ont.
Niagara Falls, Ont.
Toronto, Ont.
Windsor, Ont.
Halifax, N.S.
Yarmouth, N.S.

HSPF 8.9 to 10.6

Kamloops, B.C.
Prince Rupert, B.C.
Lethbridge, Alta.
Medicine Hat, Alta.
Maple Creek, Sask.
Barrie, Ont.
Kingston Ont.
Kitchener, Ont.
London, Ont.
North Bay, Ont.
Ottawa, Ont.
Sault Ste. Marie, Ont.
Sudbury, Ont.
Montreal, Que.
Québec, Que.
Sherbrooke, Que.
Moncton, N.B.
Saint John, N.B.
Amherst, N.S.
Sydney, N.S.
Charlottetown, P.E.I.
Grand Bank, N.L.
St. John's, N.L.

HSPF 8.7 to 10.4

Prince George, B.C.
Banff, Alta.
Calgary, Alta.
Edmonton, Alta.
Peace River, Alta.
Prince Albert, Sask.
Regina, Sask.
Saskatoon, Sask.
Brandon, Man.
Winnipeg, Man.
Thunder Bay, Ont.
Timmins, Ont.
Chicoutimi, Que.
Rimouski, Que.
Shawinigan, Que.
Edmundston, N.B.

Note: Indicated values represent the range from "standard-efficiency" to "high-efficiency" equipment.

Actual energy savings will vary depending on the local climate, the efficiency of the existing heating system, the costs of fuel and electricity, the size of the heat pump installed, and its coefficient of performance at CSA rating conditions. Later in this booklet, heating energy-cost comparisons will be made between earth-energy systems and electric heating systems, as well as air-source heat pumps.

Domestic Hot Water Heating

EESs also provide savings in domestic hot water costs. Some have a desuperheater that uses some of the heat collected to preheat hot water; newer designs can automatically switch over to heat hot water on demand. These features can reduce your water heating bill by 25 to 50 percent.

Maintenance

EESs require little maintenance on your part. Required maintenance should be carried out by a competent service contractor, who should inspect your unit once a year.

- As with air-source heat pumps, filter and coil maintenance has a dramatic impact on system performance and service life. A dirty filter, coil or fan can reduce airflow through the system. This will reduce system performance and can lead to compressor damage if it continues for extended periods.

- The fan should be cleaned to ensure that it provides the airflow required for proper operation. The fan speed should be checked at the same time. Incorrect pulley settings, a loose fan belt or incorrect motor speed can all contribute to poor performance.

- Ductwork should be inspected and cleaned as required to ensure that airflow is not restricted by loose insulation, abnormal buildup of dust or other obstacles, which occasionally find their way through the grilles.

- Be sure that vents and registers are not blocked by furniture, carpets or other items that would impede airflow.

- In open systems, mineral deposits can build up inside the heat pump's heat exchanger. Regular inspection and, if necessary, cleaning by a qualified contractor with a mild acid solution is enough to remove the buildup. Over a period of years, a closed-loop system will require less maintenance because it is sealed and pressurized, eliminating possible buildup of minerals or iron deposits.

Service contracts are similar to those for oil and gas furnaces.

Operating Costs

The operating costs of an earth-energy system are usually considerably lower than those of other heating systems, because of the savings in fuel. Qualified heat pump installers should be able to give you information on how much electricity a particular earth-energy system would use.

However, the relative savings will depend on whether you are currently using electricity, oil or natural gas, and on the relative costs of different energy sources in your area. By running a heat pump, you will use less gas or oil, but more electricity. If you live in an area where electricity is expensive, your operating costs may be higher. The payback on an investment in an earth-energy system may be anywhere up to a decade or more. Later in this booklet, operating cost estimates are provided for EESs.

Life Expectancy and Warranties

EESs have a life expectancy of about 20 to 25 years. This is higher than for air-source heat pumps because the compressor has less thermal and mechanical stress, and is protected from the environment.

Most ground-source heat pump units are covered by a one-year warranty on parts and labour, and some

manufacturers offer extended warranty programs. However, warranties vary between manufacturers, so be sure to check the fine print.

Heating Energy Cost Comparison: Heat Pump and Electric Heating Systems

Factors Affecting Heating Cost Comparisons

As stated earlier, the relative savings you can expect from running a heat pump to provide heating in your home depend on a number of factors, including:

- The cost of electricity and other fuels in your area.
- Where your home is located – severity of winter climate.
- The type and the efficiency of the heat pump you are considering – whether closer to the least energy-efficient or most energy-efficient HSPF or COP shown in Figures 4, 9 and 10.
- How the heat pump is sized or matched to the home – the balance point below which supplementary heating is required.

Comparison Results

Table 2 (page 44) shows estimated heating energy costs for eight different heat pumps, an electric furnace, and an oil furnace. Seven locations across Canada have been selected

for the purposes of this comparison. Six of these locations are cities, while one, rural central Ontario, is a region. Each has unique electricity costs. Results in other cities in the same climate region may differ, due to variations in electricity costs.

A range of annual energy costs is provided by region for each heating system. This accounts for variations in equipment efficiency, size of house or annual heating requirements, and the ratio of heat pump to house heat loss. According to Table 2, the lowest operating costs for all systems are found in Vancouver, which has the warmest climate. The highest operating costs for most systems are found in rural central Ontario. In all of these estimated cases, heat pump systems have lower annual heating energy costs than electric or oil furnaces. Also note that in all locations, ground water EESs have lower operating costs than closed-loop EESs.

The comparisons shown in Table 2 include only energy costs for space heating. For some heat pumps equipped with a desuperheater, domestic water heating costs can be reduced by 25 to 50 percent. This would increase the savings and improve the payback on investment for these systems. Furthermore, there may be payback and energy savings for those heat pumps, which can be used to meet space cooling requirements.

Table 2:

Heat Pump and Conventional Heating System - Heating Energy Cost Comparison

Location	Furnace with Air Conditioning		Air-Source Add-on to Oil Furnace	
	Electric 100% AFUE	Oil 78% AFUE	Standard Efficiency	High Efficiency
Vancouver	$405-$727	$441-$786	$139-$258 *3.6-5.2*	$125-$232 *4.1-6.1*
Calgary	$1,128-$1,907	$930-$1,536	$634-$1,053 *3.5-4.8*	$597-$985 *3.7-5.2*
Winnipeg	$1,057-$1,776	$1,290-$2,128	$867-$1,402 *2.3-3.4*	$837-$1,346 *2.6-3.8*
Rural Central Ontario (North Bay)	$1,509-$2,551	$1,072-$1,764	$806-$1,341 *4.4-5.8*	$758-$1,251 *4.4-6.0*
Toronto (Etobicoke)	$1,082-$1,854	$803-$1,338	$490-$825 3.8-5.2	$452-$755 4.0-5.7
Montreal	$832-$1,417	$716-$1,190	$462-$766 *4.3-5.9*	$433-$712 *4.5-6.5*
Halifax	$1,068-$1,833	$836-$1,397	$452-$772 *2.7-3.7*	$414-$701 *2.9-4.1*

Notes to Table 2:

1 – Electricity prices are residential runoff rates as of November 2003, as supplied by local utilities. Rates varied from a low of 5.16¢ per kWh in Winnipeg to a high of 8.67¢ per kWh in Toronto.

2 – Oil prices are "typical" prices from local suppliers as of November 2003. Prices varied from 38.9¢ per litre in Montréal to 50¢ per litre in Halifax.

3 – AFUE: Annual Fuel Utilization Efficiency (seasonal efficiency).

4 – Simple payback period (shown in italics) is based on heating cost savings and initial cost. The initial cost for air-source heat pump systems is the additional cost from an air conditioner to the heat pump. The initial cost for EES heat pump systems is the full installed cost of the heat pump.

5 – HVAC Advisor 2.0 software, developed by NRCan, was used for all the cost simulations.

(Energy cost range in $/yr.)

(Simple payback period ranges in years shown in italics below energy cost ranges)

Air-Source with Elec. Resistance Backup		**Ground Water ESS**		**Closed-Loop ESS**	
Standard Efficiency	High Efficiency	Standard Efficiency	High Efficiency	Standard Efficiency	High Efficiency
$138–$258	$125–$232	$170–$339	$141–$282	$197–$394	$165–$329
4.0–5.9	*4.6–6.9*	*14.6–17.1*	*14.2–17.0*	*29.7–33.8*	*26.5–31.2*
$689–$1,137	$650–$1,063	$432–$863	$365–$730	$488–$975	$410–$820
2.2–3.2	*2.4–3.6*	*4.9–5.3*	*4.9–5.3*	*9.6–10.3*	*8.8–9.4*
$750–$1,225	$717–$1,162	$332–$665	$281–$562	$375–$751	$316–$632
3.1–4.6	*3.3–5.1*	*4.6–5.0*	*4.7–5.2*	*8.7–9.3*	*8.3–9.1*
$935–$1,531	$882–$1,430	$453–$905	$382–$763	$515–$1,030	$432–$864
1.8–2.7	*2.0–3.0*	*3.4–3.8*	*3.5–3.9*	*6.4–7.0*	*6.2–6.8*
$529–$873	$491–$801	$282–$493	$235–$411	$326–$571	$273–$477
2.0–3.0	2.2–3.4	4.3–5.2	4.6–5.5	8.0–9.6	7.9–9.6
$484–$796	$454–$738	$314–$627	$264–$528	$357–$713	$299–$599
2.9–4.3	*3.2–4.9*	*6.9–7.4*	*6.8–7.6*	*13.5–14.1*	*12.3–13.5*
$471–$791	$432–$719	$280–$490	$233–$409	$324–$567	$271–$474
1.6–2.4	*1.8–2.7*	*3.8–4.6*	*4.0–4.8*	*7.0–8.5*	*7.0–8.4*

6 – The above costs are for space heating only. EESs are commonly equipped with a desuperheater to facilitate water heating. Desuperheaters can reduce electric water heating bills by $100 to $200 per year. Adding this savings to the space heating operating savings would reduce the payback period of an EES.

7 – The above costs are based on the HSPFs of Figures 7, 14 and 15 and house insulation values of RSI-3.5 (R-20) for walls, RSI-5.3 (R-30) for the roof, RSI-0.39 (R-2.2) for windows and RSI-1.8 (R-10) for the basement.

8 – The cost of equipment for the payback period analysis was derived from the data of RSMeans and other sources. These costs were adjusted to reflect local costs according to the location factors supplied by RSMeans.

Related Equipment

Upgrading the Electrical Service

Generally speaking, it is not necessary to upgrade the electrical service when installing an air-source add-on heat pump. However, the age of the service and the total electrical load of the house may make it necessary to upgrade.

A 200 ampere electrical service is normally required for the installation of either an all-electric air-source heat pump or a ground-source heat pump.

Supplementary Heating Systems

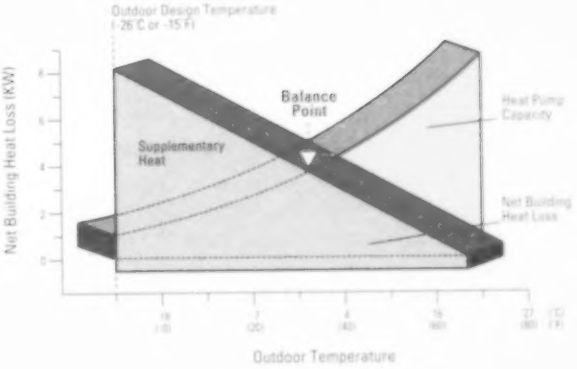
Air-Source Heat Pump Systems

Most heat pump installations require a supplementary heating system. Air-source heat pumps are usually set to shut off at either the thermal or economic balance point. In the case of an air-source heat pump, supplementary heat (also called backup or auxiliary heat) may also be required during the defrost cycle.

Supplementary heat can be supplied by any type of heating system, provided that it can be activated by the thermostat that controls the heat pump. However, most supplementary heating systems are central furnaces that use oil, gas or electricity. Many new EES installations use duct heaters to supply auxiliary heat.

Figure 16 shows the thermal balance point for a typical air-source heat pump. To the right of the thermal balance point, the heat pump is capable of satisfying all of the home's heating requirements. To the left of the thermal balance point, the house heat loss is greater than the heat pump's capacity; this is when supplementary heat is required in addition to the heat pump's capacity.

Figure 16: *Balance Point for a Typical Air-Source Heat Pump*



In the shaded area of the graph, the heat pump can operate in two ways. If heat pump operation is unrestricted by outdoor temperature, it will operate to satisfy first stage heating requirements each time heat is called for by the thermostat (see the upcoming sections on thermostats, pages 48–49). When second stage heat is called for, the heat pump shuts off if it is an add-on unit, or continues to operate if it is an all-electric heat pump system, and the supplementary heating system provides heat until all heating requirements have been satisfied.

If heat pump operation is restricted, an outdoor temperature sensor shuts the heat pump off when the temperature falls below a preset limit. Below this temperature, only the supplementary heating system operates. The sensor is usually set to shut off at the temperature corresponding to the economic balance point, or at the outdoor temperature below which it is cheaper to heat with the supplementary heating system instead of the heat pump.

Earth-Energy Systems

Earth-energy systems continue to operate regardless of the outdoor temperature. The supplementary heating system only provides heat that is beyond the rated capacity of the EES.

Figure 16:

In the shaded area of the graph, the heat pump can operate in two ways. If heat pump operation is interrupted by outdoor temperature, it will operate to satisfy first-stage heating requirements each time heat is called for by the thermostat (see the upcoming sections on thermostats, pages 48–49). When second-stage heat is called for, the heat pump shuts off if it is an add-on unit, or continues to operate if it is an all-electric heat pump system, and the supplementary heating system provides heat until all heating requirements have been satisfied.

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Earth-Energy Systems

Earth-energy systems continue to operate regardless of the outdoor temperature. The supplementary heating system only provides heat that is beyond the rated capacity of the EES.

Conventional Thermostats

Most residential heat pump systems are installed with a "two-stage heat/one-stage cool" indoor thermostat. Stage one calls for heat from the heat pump if the temperature falls below the preset level. Stage two calls for heat from the supplementary heating system if the indoor temperature continues to fall below the desired temperature.

The most common type of thermostat used is the "set and forget" type. The installer consults with you prior to setting the desired temperature. Once this is done, you can forget about the thermostat; it will automatically switch the system from heating to cooling mode or vice versa.

There are two types of outdoor thermostats used with these systems. The first type controls the operation of the electric resistance supplementary heating system. This is the same type of thermostat that is used with an electric furnace. It turns on various stages of heaters as the outdoor temperature drops progressively lower. This ensures that the correct amount of supplementary heat is provided in response to outdoor conditions, which maximizes efficiency and saves you money. The second type simply shuts off the air-source heat pump when the outdoor temperature falls below a specified level.

Thermostat setback may not yield the same kind of benefits with heat pump systems as with more conventional heating systems. Depending upon the amount of the setback and temperature drop, the heat pump may not be able to supply all of the heat required to bring the temperature back up to the desired level on short notice. This may mean that the supplementary heating system operates until the heat pump "catches up." This will reduce the savings that you might have expected to achieve by installing the heat pump.

Electronic Thermostats

Programmable heat pump thermostats are available today from most heat pump manufacturers and their representatives. Unlike conventional thermostats, these thermostats achieve savings from temperature setback during unoccupied periods, or overnight. Although this is accomplished in different ways by different manufacturers, the heat pump brings the house back to the desired temperature level with or without minimal supplementary heating. For those accustomed to thermostat setback and programmable thermostats, this may be a worthwhile investment. Other features available with some of these electronic thermostats include the following:

- Programmable control to allow for user selection of automatic heat pump or fan-only operation, by time of day and day of the week.
- Improved temperature control, as compared to conventional thermostats.
- No need for outdoor thermostats, as the electronic thermostat calls for supplementary heat only when needed.
- No need for an outdoor thermostat control on add-on heat pumps.

Setback savings of 10 percent are possible, with one setback period of eight hours each day in most Canadian locations. Two such periods per day can result in savings of 15 to 20 percent.

Heat Distribution Systems

Heat pumps require distribution systems that handle airflow rates of 50 to 60 litres per second (L/s) per kW, or 400 to 450 cubic feet per minute (cfm) per ton of cooling capacity. This is approximately 20 to 30 percent higher than the flow rates required by central, forced-air furnaces. Restricting

airflow rates decreases efficiency, and damage to the compressor can result if they are severely reduced for extended periods of time. Keep air filters clean and have the air coil cleaned if filter maintenance has been neglected.

New heat pump systems should be designed according to established practice. If the installation is an add-on, or a conversion, the existing duct system should be carefully examined to ensure that it is adequate.

Answers to Some Commonly Asked Questions

I've heard that heat pumps are very noisy. Is it possible to buy one that won't disturb my neighbours or me?

Yes. While there are no industry standards governing allowable noise levels, manufacturers usually publish this information in their product literature. The ratings are given in bels. The bel ratings increase as the heat pumps get louder. Remember, too, that noise generated by this type of equipment must not exceed the levels set out in municipal by-laws. Proper attention to installation will also reduce noise levels for both owner and neighbour.

How can I find a good contractor to purchase a heat pump from?

Selecting a reputable contractor is a key consideration in any decision to buy or modify a heating system. The following tips should help you to choose a firm:

- Ensure that the contractor is qualified to install and maintain the equipment.
- The contractor should calculate the heating and the cooling loads for the house. He or she should be able to explain this to you.

- The contractor should ensure that the ductwork is designed to provide adequate airflow and distribution to all areas of the house. If the system is an add-on, the contractor should examine the existing ductwork to see if it is adequate, since a heat pump system may require greater airflow than the ductwork was designed to handle.
- If the unit is an add-on, the contractor should ensure that the existing furnace, control system and chimney are in good working order.
- The contractor should ensure that the electrical system can accommodate the increased load brought on by the heat pump.
- The contractor should be willing to provide you with information on the unit, its operation and warranties, and to offer a service contract on the installation. The contractor should be prepared to guarantee the installation work.

In addition, follow the usual process for selecting a contractor: ask friends and relatives for referrals; get firm (written) quotes from at least two firms; check with previous clients to see if they were satisfied with the equipment, installation and service provided; and follow up with the Better Business Bureau to find out if there are any outstanding claims against the contractor. If you know which brand you would like to have installed, the manufacturer may recommend a contractor in your area.

I have heard that there are problems with compressors if they are outside during the winter in Canada. Will this affect the performance and durability of a heat pump?

Studies have shown that the service life of air-source heat pumps is shorter in northern climates than in southern climates. Climate affects the total hours of operation. In Canada, the main mode of operation is the heating cycle. The heating cycle imposes more difficult conditions on the heat pump. However, these same studies indicate that the skill of the installer and the maintenance program followed by the homeowner may have as much or more impact on the service life of the unit.

Other studies have shown that a heat pump will likely require no more than one compressor change over the course of its useful life.

Do municipal by-laws affect the use of heat pumps?

Some municipalities have enacted by-laws that require heat pumps to have specific minimum clearances to lot lines and specify that they must maintain noise levels below 45 decibels (normal talking level). Check with your local municipal office to find out if such by-laws are in effect, or if there are any additional requirements.

Your local electrical utility may offer technical advice and publications on heat pumps.

For more information on earth-energy systems, you can obtain a copy of *Residential Earth Energy Systems: A Buyer's Guide* from the Renewable and Electrical Energy Division of Natural Resources Canada, at **www.canren.gc.ca/prod_serv/index.asp?CaId=163&PgId=910**.

Also, you can contact the following organization for information on earth-energy systems:

Earth Energy Society of Canada
124 O'Connor Street, Suite 504
Ottawa ON K1P 5M9
Tel.: (613) 371-3372
Fax: (613) 822-4987

Need More Information?

Take the One-Tonne Challenge

It is a national effort to take action on climate change. The One-Tonne Challenge calls on each of us to reduce our annual greenhouse gas emissions by one tonne, or about 20 percent. By using energy more efficiently and producing less waste, you can protect our environment, improve air quality and cut your energy costs. A one-tonne reduction can be achieved with big changes, or with a number of small, simple changes. Discover lots of useful tips in *Your Guide to the One-Tonne Challenge*. Get your copy by visiting **www.climatechange.gc.ca** or by calling 1 800 O-Canada (1 800 622-6232) or 1 800 465-7735 (teletype for the hearing-impaired).

Order Free Publications From the OEE

The Office of Energy Efficiency (OEE) of Natural Resources Canada offers many publications that will help you understand home heating systems, home energy use and transportation efficiency. These publications explain what you can do to reduce your energy use and maintenance costs while increasing your comfort and helping to protect the environment.

EnerGuide for Renovating Your Home

Keeping the Heat In is a guide to all aspects of home insulation and draftproofing. Whether you plan to do it yourself or hire a contractor, this 134-page book can help make it easier. Fact sheets are also available on air-leakage control, improving window energy efficiency and moisture problems. Consider getting the expert unbiased advice of an EnerGuide for Houses evaluation before you renovate. Our telephone operators can connect you with an advisor in your local area.

EnerGuide for Home Heating and Cooling

If you are interested in a particular energy source, the OEE has booklets on heating with electricity, gas, oil, heat pumps and wood. Other publications are available on heat recovery ventilators, wood fireplaces, gas fireplaces, air conditioning your home, and comparing home heating systems.

EnerGuide for Choosing the Most Energy-Efficient Products

When shopping for household appliances, office equipment, lighting products, and windows and doors, consult the OEE's series of consumer's guides. They will help you know what to look for when it comes to energy efficiency.

The EnerGuide label, which is affixed to all new major electrical household appliances and room air conditioners, helps you compare the energy ratings of all models sold in Canada. EnerGuide ratings are also listed in the OEE's annual directories of major electrical household appliances and room air conditioners.

Every New House Should Be This Good

R-2000 homes are the best-built, most comfortable homes in Canada, and they use up to 50 percent less energy than conventional dwellings. R-2000 homes feature state-of-the-art heating systems, high levels of insulation and whole-house ventilation systems that provide continuous fresh air to all rooms. Subject to quality assurance checks during the construction process, once completed, R-2000 homes are certified as being energy-efficient.

Buying, Driving and Maintaining Your Car

For information on vehicle fuel consumption, look for the EnerGuide label that appears on every new automobile, van and light-duty truck for sale in Canada. It helps you compare different vehicles' city and highway fuel consumption ratings and estimated annual fuel costs. You can also check the OEE's *Fuel Consumption Guide*, produced annually, which provides the same information for all vehicles. The OEE's EnerGuide for Vehicles Awards also recognize the vehicles with the lowest fuel consumption in different categories.

Also available is the OEE's *Car Economy Calculator*, a fuel log that helps you calculate your fuel consumption and savings. The OEE's *AutoSmart Guide* provides detailed fuel efficiency information and offers tips on purchasing, operating and maintaining personal vehicles.

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The One-Tonne Challenge asks Canadians to reduce their annual greenhouse gas emissions by 20% or about one tonne.

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